RESHAPE IMPLEMENTATION OPTIONS STUDY

Presentation to the Administrator

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STUDY APPROACH

- Focus in three areas
- Space Segment
  - Spacecraft and Mission Architectural Strategies
  - Advanced Instrument Concepts and Technology
- Information Systems
  - ESDIS Management Assessments
  - Cost savings
- Commercial Opportunities
  - Strategy to increase interaction between commercial vendors and MTPE Program
  - Identify barriers and pathfinder concepts

Critical Assumptions for Study

- Use 24 EOS measurements as baseline requirements
- Must respond to NRC/BSD recommendations to:
  - Avoid delay of PM-1 and CHEM-1 measurements
  - New approaches to Information systems architecture and management
- Maintain international and interagency commitments

24 EOS MEASUREMENTS

- ATMOSPHERE
  - Cloud Properties (amount, optical properties, height)
  - Radiative Energy Fluxes (top of atmosphere, surface)
  - Precipitation
  - Tropospheric Chemistry (ozone, precursor gases)
  - Stratospheric Chemistry (ozone, ClO, BrO, OH, trace gases)
  - Aerosol Properties (stratospheric, tropospheric)
  - Atmospheric temperature
  - Atmospheric humidity
  - Lightning (events, area, flash structure)
- Ocean
  - Surface Temperature
  - Phytoplankton and Dissolved Organic Matter
  - Surface Wind Fields
  - Ocean Surface Topography (height, waves, sea level)

24 EOS MEASUREMENTS (cont.)

- LAND
  - Land-cover and Land-use Change
  - Vegetation Dynamics
  - Surface Temperature
  - Fire occurrence (extent, thermal anomalies)
  - Volcanic Effects (frequency of occurrence, thermal anomalies, impact)
  - Surface Wetness
- SOLAR Radiation
  - Total Solar Irradiance
  - Ultraviolet Spectral Irradiance
- CRYOSPHERE
  - Land Ice (ice sheet topography, ice sheet volume change, glacier change)
  - Sea Ice (extent, concentration, motion, temperature)
  - Snow Cover (extent, water equivalent)

Today's Space Segment Characteristics

- Instrument Requirements and Complexity are Major Impacts on Spacecraft Bus
- Current Approach Requires Custom Built Spacecraft
  - Instrument accommodation requirements drive spacecraft costs
  - One or Two Major instruments per mission drive the spacecraft requirements
- Science Co-registration requirements drive single spacecraft approach

Space Segment Findings

- Infusion of technology can lead to dramatic savings from advanced instruments
  - Have identified concepts for some “high payoff” instruments
    - In some cases functionality of two or more instruments may be packaged into a small instrument
- Achieving same measurement sets with *fewer, smaller, more capable instruments*
    - Reduced instrument resource requirements provide cascading reductions in spacecraft and launch vehicle costs

Space Segment Findings (cont.)

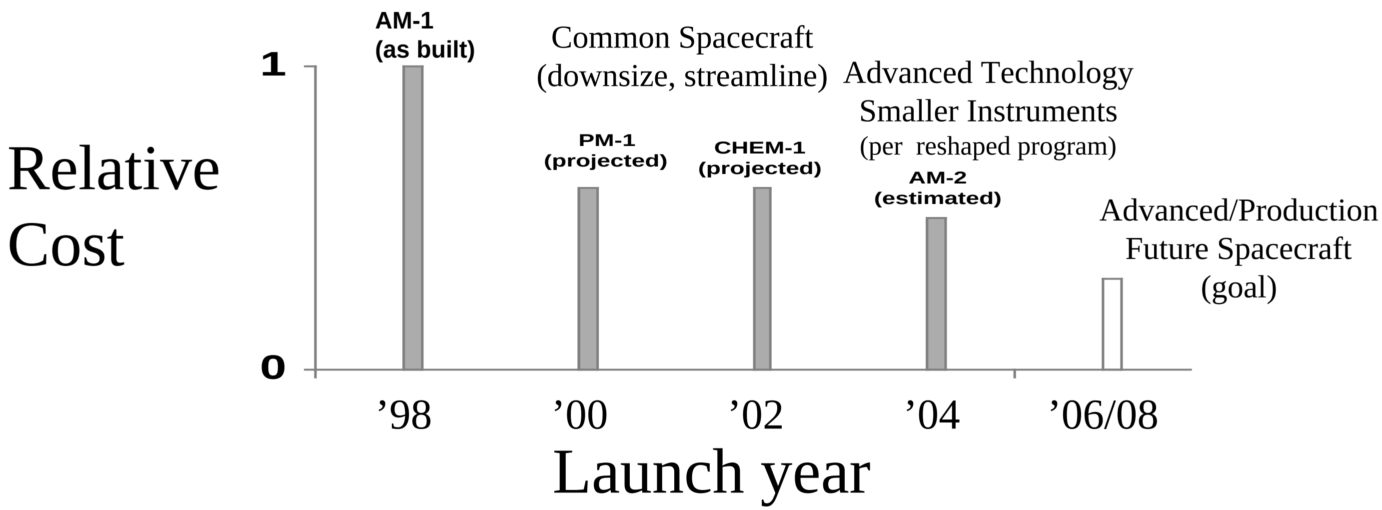
- Simply breaking-up platforms does not save money
  - Assessed the EOS Reshape baseline for the PM-1, CHEM-1 and AM-2 missions
    - Information solicited from 5 vendors of small commercial spacecraft
      - Responses (without supporting data) were received from 3
      - These quick turn-around responses, if taken a face value, showed reduced costs for the multiple satellite option
    - JPL In-house team synthesized, costed and compared single platform and three-satellite constellation for each of PM-1, CHEM-1, & AM-2 (all include launch costs)
    - Breaking up the platforms into multiple smaller satellites showed no cost benefit
      - PM/CHEM-1 costs increased 30%
      - AM-2 costs increased 60%

Space Segment Findings (cont.)

- Even partial suites of the current instruments require custom spacecraft
- Factors of two to five reduction in instrument accommodation requirementts are necessary to acheive substantial reductions in mission costs
- Cost break may be possible in future missions if low-cost production-type satellites (e.g., Iridium) can be used
    - A paradigm shift is necessary to achieve this (i.e., instruments driven not only by science but also by cost of accommodation)
    - Substantial work by scientists, engineers and managers in a true “teaming” mode will be necessary to establish the viability of this approach

Space Segment Findings (cont.)

- Program is currently on a path to lower costs



Cost for Spacecraft Infrastructure and Launch on a per Instrument Basis

Costs (per instrument) for Spacecraft Infrastructure and Launch are Declining

- AM-1 costs typical for earth observing mission planned during the 80’s
- Common spacecraft costs reduced through spacecraft downsizing and management streamlining initiatives
- AM-2 costs reduced by using advanced technology to reduce instrument size and resource requirements
- Future satellite goal to take advantage of low-cost production-type satellites

Spacecraft Technology Challenges

- Instruments (5-7)
- Space Industry Culture (5-6)
- Power System (8-9)
- Onboard processing and data storage (8-9)
- Thermal management (9-10)
- Guidance Navigation and Control (6-7)
- Operations and communications (6-7)
- Propulsion (7-8)
- Launch vehicles (5-6)
- Ground stations (7-8)
- Spacecraft manufacturing cycle (8-9)

◆ **Aggressive R&D program can achieve required technology confidence for new start (instruments and spacecraft) in approximately three years**

Space Segment Recommendations

- The implementation of the "Reshaped" program should increase the emphasis on balancing and trading costs and science requirements
  - Choose the language and selection criteria of future AOs to encourage best science value (cost/benefit trade)
  - Invest in advanced technology to allow the use of fewer, smaller and more capable instruments to achieve the 24 measurement sets
    - Promote rethinking of instrument concepts and groupings to minimize overlaps, reduce support requirements and improve performance
    - Structure a technology development and insertion program to develop advanced instruments that can be more easily accommodated on inexpensive spacecraft
    - Perform multiple concept studies with providers of inexpensive and "production" spacecraft to define the cost effective envelope of instrument support capabilities

Space Segment Recommendations

- Coordinate the development of a full end-to-end plan for the insertion of new technology including appropriate mission concept studies
  - To ensure realization of the savings of the “advanced technology” strategy, the GSFC Code 170 should lead and coordinate this process
    - Assure completion of the advanced technology roadmaps
    - Need is to apply technology supporting mission goals
    - Define with NASA Office of Mission to Planet Earth (HQ Code Y) a strategy for full concurrent participation by all parties (management, technologists (New Millennium and others) and scientists)

Space Segment Recommendations

- Extend and expand the Reshape program approach to infuse new technology
  - Periodically reassess (through Biennial Review) the opportunities for technology insertion and its impacts on architectures and strategies
  - Integrated science, engineering and management teams should be established for all of the -2 mission studies to allow in-depth science/cost trades in developing new instrument and mission concepts
  - For CHEM-1, an appropriately aggressive technology insertion effort is planned. This should be encouraged as much as possible and is a precursor for the -2 mission

Information System Findings

- The open data system architecture developed by the program is sound and flexible
- Science needs and data policy conflict with some commercial interests
- Technology is COTS validation and integration oriented and scheduled for insertion at major system upgrades
- The major user (research community) does not "own" performance/cost trade responsibility
- The project is building dedicated infrastructure while underutilizing existing relevant infrastructure
- Significant savings have already been made in implementing the Reshaped Program.
  - This study has identified additional potential savings before CY 2000

Information System Recommendations

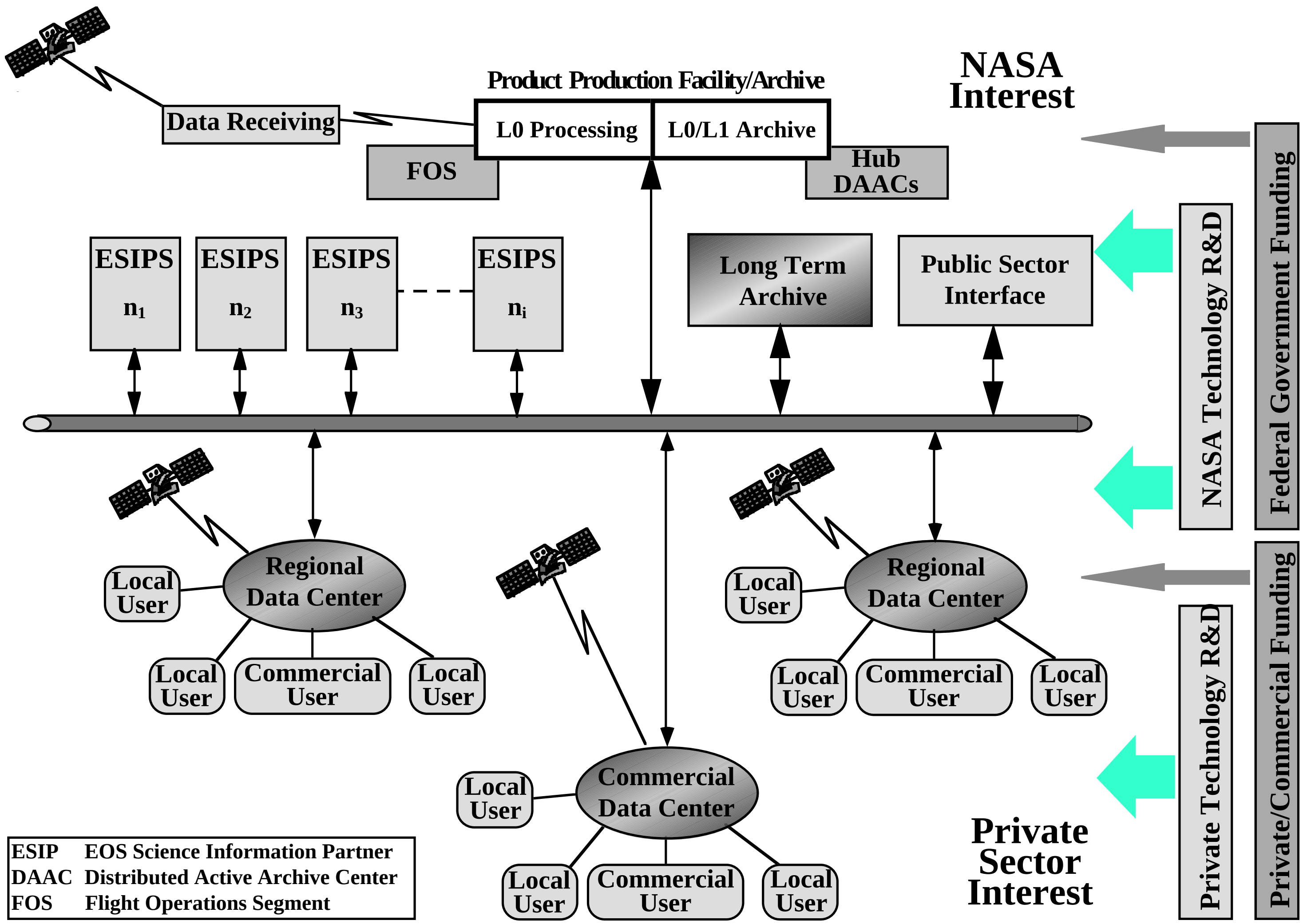
- Streamline the Reshape program implementation
  - Reduce the management and systems engineering overhead
  - Increase sharing with existing infrastructure where possible
    - Explore outsourcing options for tracking stations
    - Re-evaluate opportunities for the use of existing NASA infrastructure
    - Aggressively pursue development of other outsourcing opportunities
  - Empower DAAC managers to determine the appropriate staffing level and operations costs

Information System Recommendations

(cont.)

- Implement the External Enterprise Concept
  - Start the Federated portion of the system per the Board on Sustainable Development recommendation
    - Continue to explore the ESIP/Hub options for further cost savings
    - Test the Federated Concept now through a prototype using selected AM-1 data products and Version 0
    - Implement the complete Federated System post AM-1 (version 2)
  - Add the commercial applications and Regional Data Centers to the Federated Concept to complete the External Enterprises Concept
    - Provide a means for rapid technology infusion on a site by site basis
    - Encourage rapid adaptation to new strategies (e.g., direct broadcast communications, new data products, new applications)

Recommended External Enterprises Concept



ESIP	EOS Science Information Partner
DAAC	Distributed Active Archive Center
FOS	Flight Operations Segment

Commercial Options Findings

- There is currently a limited intersection between the needs of the MTPE science and products planned by commercial vendors (primarily land surface imaging and some ocean surface imaging)
- Opportunities exist for increasing the intersection; however, the cost benefits are difficult to quantify without cost data from new private remote sensing companies

Commercial Options Findings
(Calibration Requirements)

- Earth system science and global change research require accurate measurements over extended periods of time to detect and document quantitatively small changes independent of the instrument or platform acquiring the measurements
  - Preflight, inflight, and postflight calibration of instruments is essential
  - Traceability of calibration methods/procedures to national/international standards is required
  - Participation in and support by scientists in calibration activities assures their confidence and ownership of measurement quality

Commercial Options Findings
(Calibration Requirements (cont.))

- Current commercial data offerings are primarily focused on short term changes
  - The short term objective is to maximize the return from mapping missions
- The long term (5 year) private sector focus is on monitoring and quantifying environmental change
  - Seeks calibration and data standards suitable for use in litigation
  - MTPE calibration requirements and commercial developments will start to converge over time

Commercial Options Recommendations

- Develop options for increasing the intersection between science and commercial activities
  - Conduct a workshop in mid CY 96
  - Develop a cooperative agreement notice focused on commercial utility of the EOS data sets
  - Proactively explore MTPE calibration requirements and approaches with commercial providers to identify ways to increase intersection
  - Develop joint research opportunities for MTPE and private sector scientists to identify common calibration standards and techniques

Programmatic Findings

- The program prior to Reshaping was structured in a way that did not have clear coupling and alignment between the setting of requirements and the responsibility for budget and implementation
- The Reshape report recommended biennial reviews to examine program direction and options to ensure that the right things were being done in the best possible way

Programmatic Recommendations

- All future missions and major program changes should be evaluated on the basis of science value and full life cycle costs <u>including the costs of all accommodations</u>
  - support to orbit, communications, operations and data processing as allocable to the mission or change
  - Develop cost structures to allow better insight and enable cost sensitivity analysis for significant cases
  - Develop cost analysis tools to allow more comprehensive evaluations

Programmatic Recommendations (cont.)

- The future programmatic decision process for changes must consider all options for meeting MTPE requirements
  - Can and should be incorporated in the “Biennial Review Process” as recommended by the EOS “Reshape” Report
    - – Evaluate science return and benefits
    - – Are the data available from another agency?
      - NASA/NOAA convergence
    - – Can the data be purchased?
      - commercial options
    - – Can the data be gathered without going into space?
      - e.g., RPVs, automated ground stations
    - – What approach has the lowest life-cycle cost to gather the data
      - cost sensitivities, integrated teams, etc.

Cost Benefits Assessment

Action Area	Goal	Potential Benefit before '00	'01-'05	'05 & out
Advanced Instruments & Advanced Technology in Spacecraft	1) Drive infrastructure costs down 2) Implement New Millennium Technology 3)Sciencecraft concepts	Investment required	Moderate (credit already taken in Reshape Baseline)	High
Production Spacecraft and Standardized Interfaces	1) Leverage industry investment in "constellation spacecraft"	Investment required	Low to Moderate	Moderate to High
Information System-External Partnerships	1) Shortened response time 2) User responsibility for cost/benefit decisions 3) Expanded constituency	Investment required plus moderate payback	High	High
Information System-Streamlining	1) Lowered overhead 2) Use existing infrastructure	High (partial credit already taken in current budget)	Moderate	Moderate
Commercial Options	1) Leverage industry investment 2) Potential for new products and applications 3) Difficult to predict outcomes	Investment required in partnerships	Uncertain; possibly Moderate	Uncertain; possibly High

Conclusion

- The Reshape program approach to infuse new technology to save cost is sound
  - For AM-2 and beyond, an aggressive approach to inserting new technology can result in significantly reduced budgets
  - For PM-1 and CHEM-1, it is unlikely that alternative approaches will achieve significantly reduced costs without incurring substantial program delays
  - The Information System Reshape cost reductions were validated

Conclusion

- The Central Hub/ Federation approach in the Information System can further reduce costs
- The External Enterprise approach can substantially increase the constituency in both the commercial and non-commercial sectors
- Investing the savings in technology insertion will provide dramatic payback
  - investment needed in technology for spacecraft, instruments and the information system
  - failure to invest will result in the inability to obtain the currently budgeted cost savings